ANALYSIS OF A CASPIAN SEA VORTEX

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ABSTRACT

The origin of a small, tight cloud vortex located over the Caspian Sea as viewed by TIROS VII in late November 1963 was investigated. Charts at the mandatory levels from the surface to 500 mb. at 12-hr. intervals were examined. Possible causes of formation that were investigated included upper air circulation effects, mechanical effects induced by the Caucasus Mountains, surface heating from the sea, and association with a cold front. Evidence is presented that the cloud vortex was associated with a frontless circulation. A well-defined upper-level wind circulation is believed to be the major cause for the formation of the cloud spiral.

1. INTRODUCTION

A small, tightly knit cloud vortex appeared over the central Caspian Sea on November 20, 1963. This striking vortex was most clearly revealed by the artificial satellite TIROS VII on orbital pass 2278, photograph number 27 taken at 0924 GMT. The "Picture of the Month" series [1] suggested three possible causes for the formation of this cloud spiral. These were: (1) association with a weak cold front analyzed over the Caspian Sea, (2) mechanically induced circulation caused by flow across the high mountains to the west, or (3) thermally induced circulation caused by surface heating from the relatively warm sea. Dzhordzhio and Lyapina [2] proposed that cyclogenesis occurred along an old polar front, the cyclogenesis being suppressed somewhat by a warm ridge aloft. The purpose of this paper is to ascertain the cause of formation of this remarkable cloud spiral.

2. AVAILABLE DATA

Figure 1 shows the center of the cloud vortex located over the central Caspian Sea with trailing cloud arms north and south of the core. This photograph was gridded on an IBM 7090 by the National Weather Satellite Center at Suitland, Md. The snow-covered Caucasus Mountains are visible to the west-northwest of the cyclone. Also, another area of cloudiness showing some banded structure is seen to the north of the cloud vortex.

Conventional data are scarce in the Caspian Sea region. With the aid of the Israel Meteorological Service, surface charts and constant pressure charts for the 850-, 700-, and 500-mb. levels were obtained for 0000 GMT on November 20 and 21 and for 1200 GMT on November 20. Additional constant pressure surface data were procured for 1200 GMT on November 20 from the National Weather Records Center in Asheville, N.C.

Normal sea surface temperatures for the Caspian Sea region for November were obtained from [3].

3. ANALYSIS OF THE CYCLONE

Figures 2, 3, and 4 show the surface, 850-mb. and 500-mb. charts for 0000 GMT November 20. A small surface cyclone is well defined just west of the central Caspian Sea squeezed between two large ridges. There is no evidence of any fronts over the entire region. A

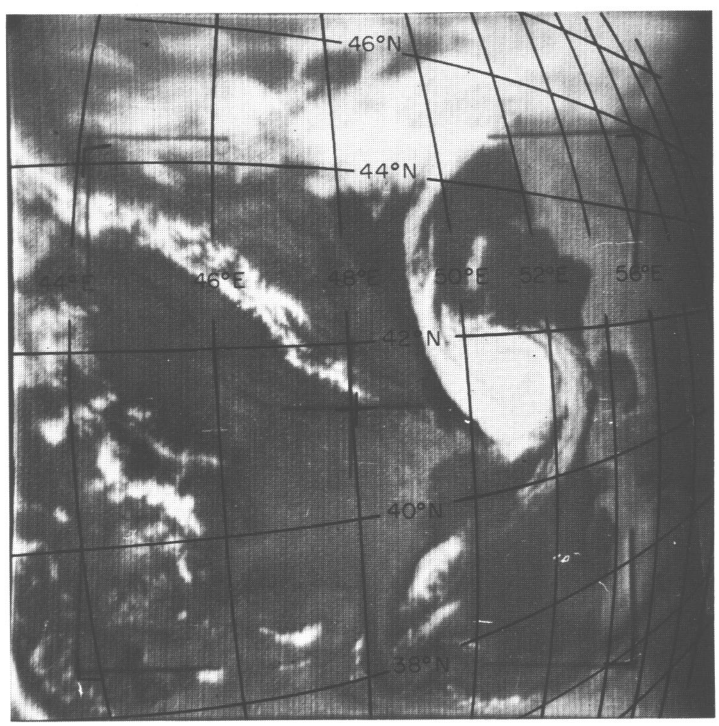

FIGURE 1.—Satellite photograph of the Caspian Sea region showing the cloud vortex on the right and the snow-covered Caucasus Mountains on the left west-northwest of the center of the cloud vortex. (TIROS VII, orbital pass 2278, camera 1, tape, frame 27, 0924 GMT, November 20, 1963.)

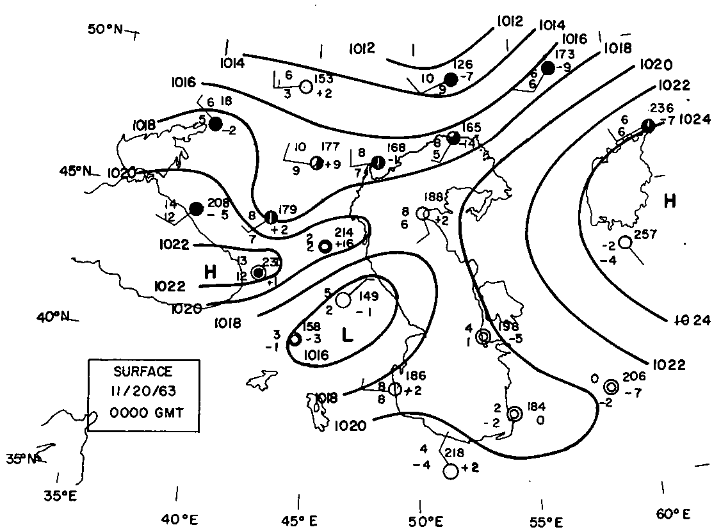

FIGURE 2.—Regional surface chart of the Caspian Sea area for 0000 GMT November 20, 1963. Temperatures are plotted in °C. and pressures in mb. Isobars are analyzed every 2 mb.

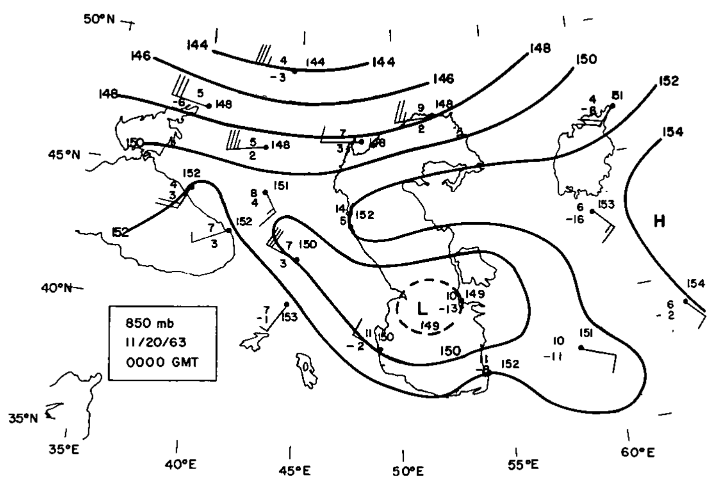

FIGURE 3.—Regional 850-mb. chart of the Caspian Sea area for 0000 GMT November 20, 1963. Heights are plotted in decameters and contours are analyzed every 2 decameters.

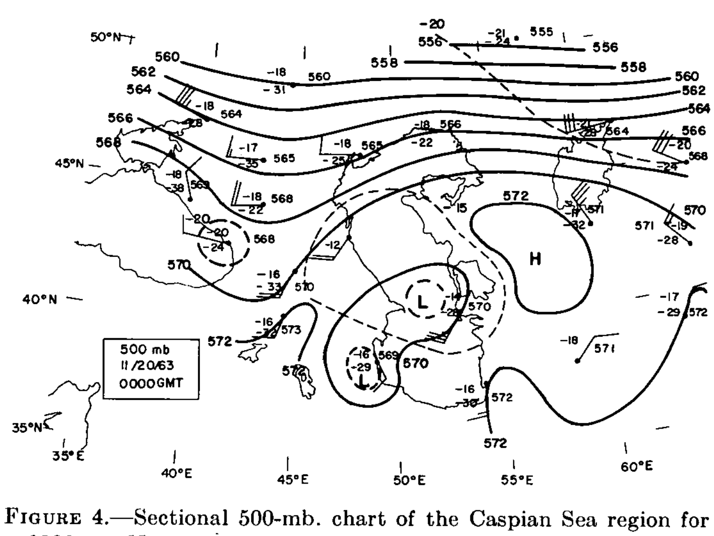

FIGURE 4.—Sectional 500-mb. chart of the Caspian Sea region for 0000 GMT November 20, 1963. Heights are plotted in decameters and contours are analyzed every 2 decameters.

well-defined Low is present at 850 mb. just west of Krasnovodsk (40.0° N., 53.0° E.). An elongated 500-mb. depression with evidence of two circulation centers is found just east of the surface center. Although there are no easterly winds observed at 500 mb. over the central Caspian Sea to indicate conclusively a closed circulation, the arrangement of the height pattern and the wind directions and strengths strongly suggest the presence of easterly winds in this area. The 850- and 700-mb. charts show a pattern similar to the 500-mb. chart except that the circulation and heights at 700 mb. suggest a sharp trough rather than a closed depression. The isotherms on the 500-mb. chart show relatively high temperatures over the central Caspian area.

By 1200 GMT the surface center and the westernmost of the two previously mentioned ridges weakened somewhat while the easternmost ridge maintained most of its strength. The surface center moved eastward to a position nearly coincident with the TIROS-viewed cloud vortex (fig. 5). A warm front that had some definite support north of the Caspian Sea looped northwestward into the vigorous Low well to the northwest of the area of interest. The steady precipitation and slight pressure falls ahead of the front constituted its main support. It seems quite likely that the banded cloud structure oriented northeast-southwest well to the north of the tight spiral was associated with this frontal activity. The slightly lower relative temperatures and west and north winds are interpreted as sea breeze effects at Fort Sevcenko (44.4° N., 47.4° E.), and Mahakala (43.0° N., 47.4° E.), respectively.

From 0000 GMT to 1200 GMT on November 20, the 500-mb. circulation weakened in spite of decreasing heights (fig. 6). The diminished wind at Krasnovodsk is evidence that this circulation had weakened in the past 12 hr. The continued presence of the northernmost of the two circulation centers in the 500-mb. depression over the Caspian Sea is suggested by gradient considerations (the 20 kt. south-southwest wind at Krasnovodsk), and persistence of a quasi-stationary upper-air feature.

All levels showed deepening between 1200 GMT November 20 and 0000 GMT November 21 in response to the approach of the vigorous system that was northwest of the Caspian Sea area at 1200 GMT. No fronts were noted on the surface chart (fig. 7) except for the remnants of the warm front found on the 1200 GMT map. The most marked changes in the 12-hr. period were at the 500-mb. level (fig. 8) where a marked depression was evident. Also, the temperatures fell still further over the central Caspian Sea at that level, −21° C. being observed at Lenkoran (38.7° N., 48.8° E.), and the closed −20° C. isotherm indicated a well-defined cut-off cold pool.

It appears from the above discussion of the surface and upper-air charts that the major cause of the formation of the cloud vortex was the favorable location of a well-defined upper-level depression. The cyclonic curvature and vorticity present with the upper-level depression

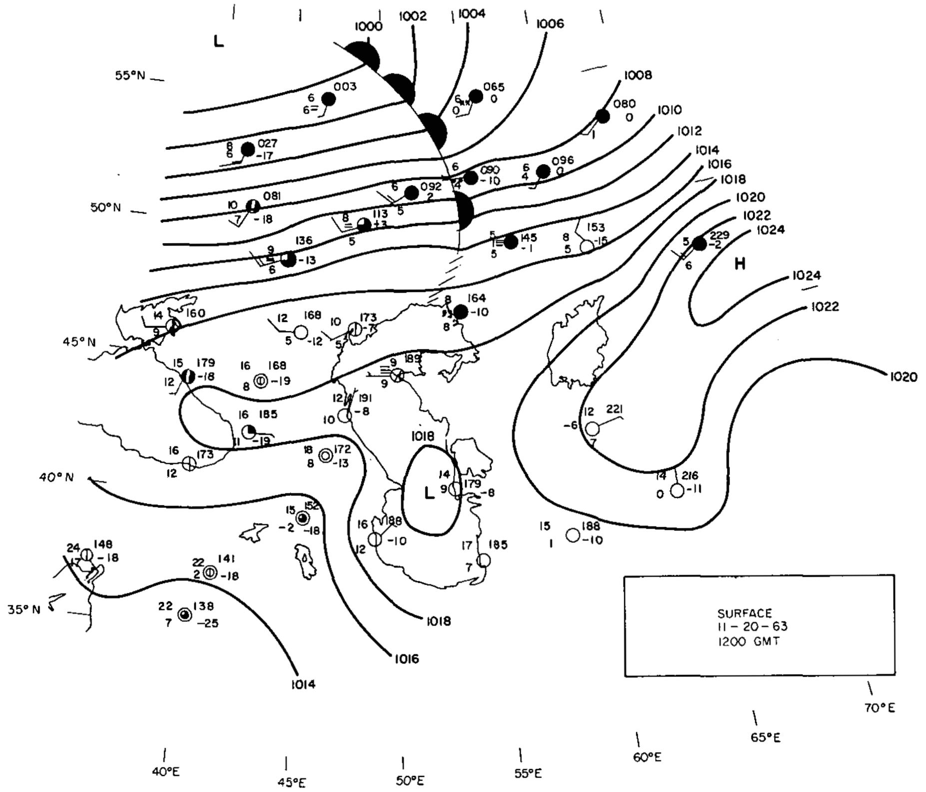

FIGURE 5.—Regional surface chart of the Caspian Sea area for 1200 GMT November 20, 1963. Temperatures are plotted in °C. and pressures in mb. Isobars are analyzed every 2 mb.

before the time of the television picture were apparently sufficient to generate the cyclonic feature that was depicted on the TIROS photograph. This argument indicates that the cloud vortex in this study probably existed for some time within a cyclone that permitted the development of the cloud spirals.

An estimate of the cloud top heights within the vortex would give some clue as to what level the cloud circulation represented. Unfortunately, there are no medium resolution atmospheric "window" radiation data available for this area concurrent with the photograph to supply such a height estimate of the cloud summits. However, some knowledge of the cloud types contained within the vortex circulation can often give some crude indication of cloud top height. The cloud types can be estimated from a method proposed by Conover [4]. The grey banded appearance of the cloud structure on the eastern edge of the vortex (fig. 1) suggests that the visible clouds there are either cirrus or a combination of altostratus and altocumulus. The brighter solid cloud mass toward the cloud vortex center appears to be (1) active nimbostratus associated with layered cloud decks; (2) stratus >1000 ft. thick; or, (3) stratocumulus >1000 ft. thick. Of these possible choices and in view of: (1) the cyclonic depression to at least 500 mb. and (2) the duration of this closed

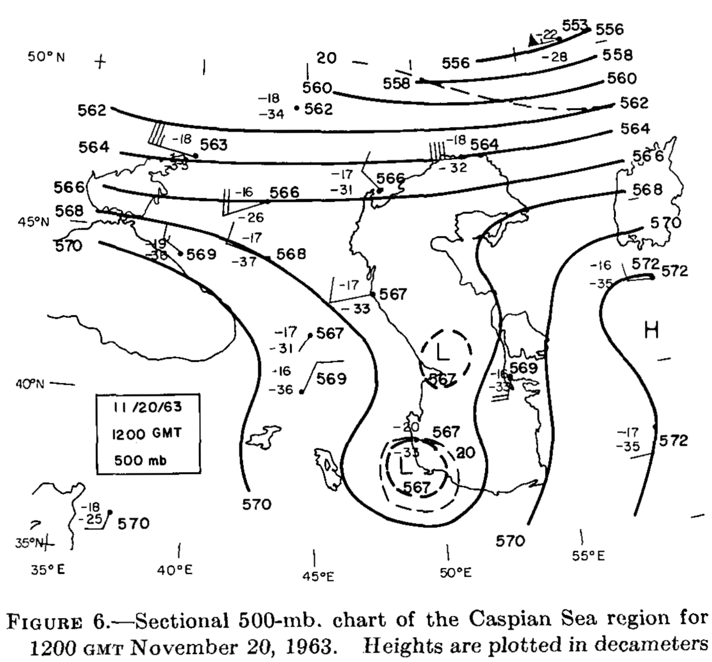

FIGURE 6.—Sectional 500-mb. chart of the Caspian Sea region for 1200 GMT November 20, 1963. Heights are plotted in decameters and contours are analyzed every 2 decameters.

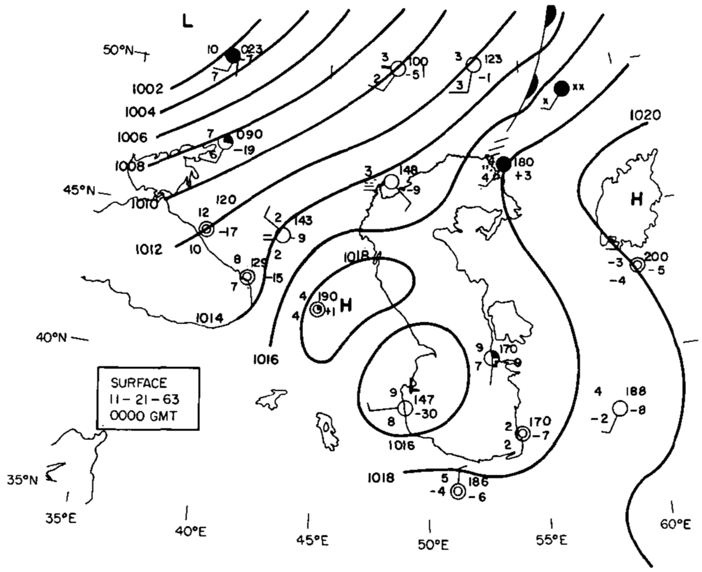

FIGURE 7.—Regional surface chart of the Caspian Sea area for 0000 GMT November 21, 1963. Temperatures are plotted in °C. and pressures in mb. Isobars are analyzed every 2 mb.

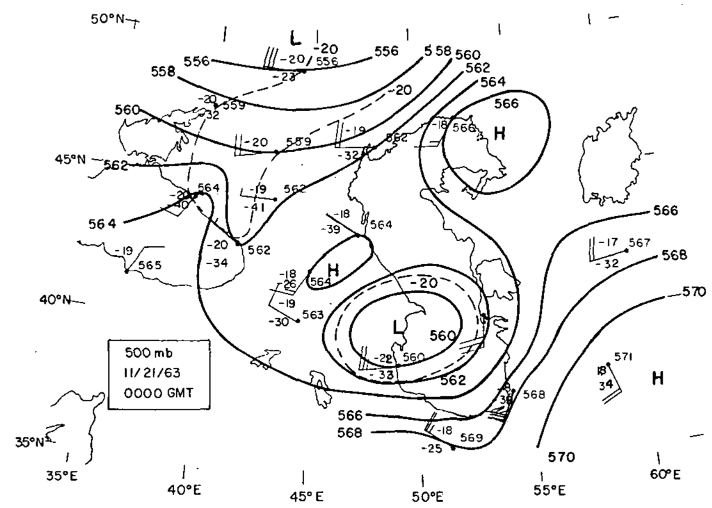

FIGURE 8.—Sectional 500-mb. chart of the Caspian Sea region for 0000 GMT November 21, 1963. Heights are plotted in decameters and contours are analyzed every 2 decameters.

circulation in the central Caspian Sea, the most likely selection would seem to be the nimbostratus associated with layered cloud decks and possible precipitation at the surface. Thus, the vortex clouds probably represent a circulation at high levels.

The Caspian Sea region is climatologically semi-arid. The 850-mb. chart for 0000 GMT November 20 (fig. 3) shows no observed dew point depression of less than 13° C. at radiosonde stations in the area where the vortex formed. Thus, it is judged that the only moisture supply at all levels up to the cloud tops sufficient to produce the clouds in this climatologically semi-arid region was the Caspian Sea itself rather than the surrounding area.

Thick layered clouds are generally formed only over moisture sources concurrent with a dynamic lifting mechanism that persists long enough to produce the clouds. This means that in order for the cloud vortex to reach the stage of development the TIROS picture shows, the upper-level feature which contributed to the cyclonic development would have had to remain almost stationary for a considerable length of time over the moisture source. The quasi-stationary state of the upper-level circulation between 0000 GMT November 20 and 0000 GMT November 21 did comply with this condition which would permit cloud development such as that shown in the TIROS photograph.

The frontal system mentioned by Dzhordzhio and Lyapina [2] and the *Monthly Weather Review* [1] may be present in a very weak fashion but it was not readily detectable from the data available to this study. The air mass properties over the Caspian Sea region appeared to be continuous as noted on the 1200 GMT surface chart (fig. 5). Two exceptions were the stations where a sea breeze was probably in progress (1200 GMT is 1500 LST on the western shore and 1600 LST on the eastern shore except for 1530 LST along the Iranian shoreline). Another factor that does not support the vortex generation by a front is the lack of a marked front 12 hr. before or after 1200 GMT on November 20 over the entire Caspian Sea region.

The flow across the Caucasus Mountains and the other surrounding high mountain ranges was quite weak up to the 500-mb. level. Further, the flow generally parallels the mountains. Thus it seems quite unlikely that the cloud spiral could have developed from any mechanical effects caused by the mountains.

The remaining suggestion from the *Monthly Weather Review* article is that the formation could have been induced by the relatively warm waters of the Caspian Sea. However, the Caspian Sea does not behave in the exact fashion as the Great Lakes in the United States. The Caspian Sea is considerably shallower than the Great Lakes and therefore cannot retain heat as well. Thus, as the air temperatures become lower in the fall, the Caspian Sea cools off comparatively quickly.

The temperatures observed at 1200 GMT on November 20 were at or slightly above the climatological sea surface temperature for the Caspian Sea in November [3]. The moisture from the Caspian Sea probably performed a more important role in the development of the visible cloud vortex than any thermal effects caused by a relatively slow cooling of the water as compared to the land in the fall.

4. CONCLUDING REMARKS

This study concludes that the favorable location of a quasi-stationary, nearly vertical upper-level depression was the major cause of the development of the tightly knit

TIROS-viewed cloud vortex over the central Caspian Sea on November 20, 1963. It is also quite possible that similar vortices exist over the Great Lakes in the fall and early winter with a combination of a well-defined upper-level circulation and the land-water temperature differences that occur during that season.

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